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Heat and Mass Transfer through a Porous Medium in a Vertical Channel with Chemical Reaction and Heat Source

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Abstract— **In this paper we deal with the non-Darcy effects on two-dimensional laminar simultaneous heat and mass transfer flow of a viscous, incompressible, electrically conducting and chemically reacting fluid through a porous medium confined in a vertical channel. The equations of continuity, linear momentum, energy and diffusion which govern the flow field are solved exactly. The behavior of the velocity, temperature and concentration, skin friction, Nusselt number and Sherwood number has been discussed for variations in the governing parameters.**

Index Terms— **Component Vertical Channel, Porous Medium, Heat Source, Chemical Reaction, Perturbation Method.**

I. INTRODUCTION

Heat transfer in the case of homogeneous fluid-saturated porous medium has been studied with relation to different applications like dynamics of hot underground springs, terrestrial heat flow through aquifers, hot fluid and ignition front displacements in reservoir engineering, heat exchange between soil and atmosphere, flow of moisture through porous industrial materials and heat exchange with fluidized beds.Mass transfer in isothermal conditions has been studied with applications to problems of mixing of fresh and salt water in aquifers, miscible displacements in oil reservoirs, spreading of solutes in fluidized beds and crystal washers, salt leaching in soils etc. Prevention of salt dissolution into lake waters near the sea shores has become a serious problem for research.

Coupled heat and mass transfer phenomenon in porous media is gaining attention due to its interesting applications. The flow phenomenon is relatively complex rather than that of the pure thermal convection process. Underground spreading of chemical wastes and other pollutants, grain storage ,evaporation cooling and solidification are the few other application areas where the combined thermo-solutal natural convection in porous media are observed .Combined heat and mass transfer by free convection under boundary layer approximations has been studied by Bejan and Khair[3],Lai and Kulacki[13] and Murthy and Singh[15].Coupled heat and mass transfer by mixed convection in Darcian fluid-saturated porous media has been analyzed by Lai[12].The free convection heat and mass transfer in a porous enclosure has been studied recently by Angirasa et al[2].The combined effects of thermal and mass diffusion in channel flows has been studied in recent times by a few authors, notably Nelson and Wood [18,19].

Lee et al [14] and others [4,5,23,25,26,27,29].In almost all these works the boundary layer formulation of Darcy’s law, the energy and diffusion equations were used. Non-Darcy effects on natural convection in porous media have received a great deal of attention in recent years because of the experiments conducted with several combinations of solids and fluids covering wide range of governing parameters which indicates that the experimental data for systems other than glass water at low Rayleigh numbers do not agree with theoretical predictions based on the Darcy flow model. This divergence in the heat transfer results has been reviewed in detail in the works of Cheng [6] and Prasad et al[21] among others.

For some industrial applications such as glass production and furnace design in space technology applications, cosmic flight aerodynamics, rocket propulsion systems, plasma physics which operate at higher temperatures, radiation effects can be significant. Soundalgekar and Takhar[24] considered the radiative free convection flow of an optically thin grey-gas past a semi-infinite vertical plate. Radiation effects on mixed convection along an isothermal vertical plate were studied by Hussain and Takhar[11]. Raptis and Perdikis[22] have studied the effects of thermal radiation and free convection flow past a moving vertical plate.Chamkha et al[6] analysed the effects of radiation on free convection flow past a semi-infinite vertical plate with mass transfer. Muthukumaraswamy and Ganesan[16] have studied the radiation effects on flow past an impulsively started

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infinite vertical plate with variable temperature. Prakash and Ogulu[20] have investigated an unsteady two-dimensional flow of a radiating and chemically reacting fluid with time.

The study of heat generation or absorption effects in moving fluids is important in view of several physical problems, such as fluids undergoing exothermic or endothermic chemical reactions. Vajravelu and Hadjinicolaou [28] studied the heat transfer characteristics in the laminar boundary layer of a viscous fluid over a stretching sheet with viscous dissipation or frictional heating and internal heat generation. Hossain et. al. [10] studied the problem of natural convection flow along a vertical wavy surface with uniform surface temperature in the presence of heat generation / absorption. Alam et al. [1] studied the problem of free convection heat and mass transfer flow past an inclined semi-infinite heated surface of an electrically conducting and steady viscous incompressible fluid in the presence of a magnetic field and heat generation. Chamkha [6] investigated unsteady convective heat and mass transfer past a semi-infinite porous moving plate with heat absorption. Hady et al. [9] studied the problem of free convection flow along a vertical wavy surface embedded in electrically conducting fluid saturated porous media in the presence of internal heat generation or absorption effect.

In many chemical engineering processes ,there does occur the chemical reaction between a foreign mass and the fluid in which the plate is moving. These processes take place in numerous industrial applications viz, polymer production, manufacturing of ceramics or glassware and food processing .Das et al[7] have studied the effects of mass transfer on flow past an impulsively started infinite vertical plate with constant heat flux and chemical reaction. Muthukumara swamy[17] has studied the effects of reaction on a moving isothermal vertical long surface with suction. Recently Gnaneswar[8] has studied radiation and mass transfer on an unsteady two-dimensional laminar convective boundary layer flow of a viscous incompressible chemically reacting fluid along a semi-infinite vertical plate with suction by taking into account the effects of viscous dissipation.

In this chapter we deal with the non-Darcy effects on two-dimensional laminar simultaneous heat and mass transfer flow of a viscous, incompressible, electrically conducting and chemically reacting fluid through a porous medium confined in a vertical channel. The equations of continuity, linear momentum, energy and diffusion which govern the flow field are solved exactly. The behavior of the velocity, temperature and concentration, skin friction, Nusselt number and Sherwood number has been discussed for variations in the governing parameters.

II. Mathematical Formulation of the Problem

We consider a coupled heat and mass transfer flow of a viscous electrically conducting fluid through a porous medium confined in a vertical channel bounded by porous flat walls in the presence of heat generating sources, transverse magnetic field effects and a first order chemical reaction. The flow is assumed to be steady, laminar and two-dimensional and the surface is maintained at constant temperature and concentration, As the plates are sufficiently long, the flow variables does not depend on the vertical and axial co-ordinates. It is also assumed that the applied magnetic field is uniform and that the magnetic Reynolds number is small so that the induced magnetic field is neglected. In addition, there is no applied electric field and all of the Hall Effect, viscous dissipation and Joule heating are neglected. All thermo physical properties are constant except the density in the buoyancy terms of the linear momentum equation which is approximated according to the Boussinesq approximation, under these assumptions, the equations describing the physical situation are given by

$$\frac{\partial v}{\partial y} = 0 \qquad (2.1)$$

$$v\,\frac{\partial u}{\partial y} = \nu\,\frac{\partial^2 u}{\partial y^2} + \beta\, g\,(T - T_e) + \beta^{\bullet}\, g\,(C - C_e) - \frac{\sigma B_0^2 u}{\rho} - \left(\frac{\nu}{k}\right) u - \frac{\delta F}{\sqrt{k}}\, u^2 \qquad (2.2)$$

$$\rho_0\, C_p\, v\,\frac{\partial T}{\partial y} = \lambda\,\frac{\partial^2 T}{\partial y^2} + Q\,(T - T_e) - \frac{\partial\,(q_R)}{\partial y}\, a \qquad (2.3)$$

$$v\,\frac{\partial C}{\partial y} = D\,\frac{\partial^2 C}{\partial y^2} - \gamma\, C \qquad (2.4)$$

where y is the horizontal or transverse coordinate, u is the axial velocity, v is the transverse velocity, T is the fluid temperature, C is the species concentration ,T_e the ambient temperature, C_e is the ambient concentration and $\rho, g, \beta, \beta^{\bullet}, \mu, \sigma, B_0, Q, D$ and γ are the density, gravitational acceleration, coefficient of thermal expansion, coefficient of concentration expansion, dynamic viscosity, fluid electrical conductivity, magnetic induction, heat generation/absorption coefficient, mass diffusion coefficient and chemical reaction parameter respectively. The physical boundary conditions for the problem are

$$u(-L) = 0,\ v(-L) = v_w,\ T(-L) = T_1,\ C(-L) = C_1 \qquad (2.5)$$
$$u(+L) = 0,\ v(+L) = v_w,\ T(+L) = T_2,\ C(+L) = C_2$$

Where $v_w>0$, T_1,T_2 and C_1,C_2 are the suction velocity, surface temperatures and concentrations on $y = \pm\ L$ respectively.

Invoking Rosseland approximation for radioactive heat flux

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$$q_r = -\frac{4\sigma^{\bullet}}{3\beta_R}\frac{\partial T'^4}{\partial y}$$

Expanding T'^4 in Taylor series about T_e and neglecting higher order terms, we get

$$T'^4 \cong 4\,T\,T_e^3 - 3\,T_e^4$$

q_r Represents the radiation heat flux in the y direction, $\sigma^{\bullet}$ the Stefan –Boltzman constant and β_R the mean absorption coefficient.In order to write the governing equations and boundary conditions in the dimensionless form, the following non-dimensional quantities are introduced

$$y' = \frac{y}{L},\; u' = \frac{u}{(\nu/L)},\; \theta = \frac{T-T_1}{T_2-T_1},\; C' = \frac{C-C_1}{C_2-C_1}$$

The equations after dropping the dashes are

$$\frac{d^2u}{dy^2} + S\frac{du}{dy} + G\,\delta(\theta+NC) - \delta(M^2+D^{-1})\,u - (\delta^2\mathrm{A})\,u^2 = 0 \quad (2.6)$$

$$\frac{d^2\theta}{dy^2} + SP\frac{d\theta}{dy} - \alpha\,P\,\theta = 0 \quad (2.7)$$

$$\frac{d^2C}{dy^2} + SSc\frac{dC}{dy} - k\,Sc\,C = 0 \quad (2.8)$$

Where $P = \frac{\mu C_p}{\lambda}$ (Prandtl Number), $Sc = \frac{\nu}{D}$ (Schmidt Number), $k = \frac{\gamma L^2}{\nu}$ (Chemical reaction parameter), $M^2 = \frac{\sigma B_0^2 L^2}{\rho_0\,\nu}$ (Hartman Number), $N = \frac{\beta^{\bullet}\Delta C}{\beta\Delta T}$ (Buoyancy ratio), $N_1 = \frac{\lambda\beta_R}{4\,\sigma^{\bullet}T_e^3}$ (Radiation parameter), $\alpha = \frac{QL^2}{\lambda}$ (Heat source parameter), $\mathrm{A} = F\,D^{-1/2}$ (Inertia parameter or Forchhimer Number).

The non-dimensional boundary conditions are

$$u(\pm1) = 0,\; \theta(-1) = 0,\; C(-1) = 0$$
$$\theta(+1) = 1,\; C(+1) = 1$$

III. SOLUTION OF THE PROBLEM

The governing equations of the flow, temperature and concentration are coupled non-linear differential equations. Assuming the porosity δ to be small, we write

$$u(y) = u_0(y) + \delta u_1(y) + \delta^2 u_2(y) + \ldots \quad (3.1)$$

$$\theta(y) = \theta_0(y) + \delta\theta_1(y) + \delta^2\theta_2(y) + \ldots \quad (3.2)$$

$$C(y) = C_0(y) + \delta C_1(y) + \delta^2 C_2(y) + \ldots \quad (3.3)$$

Substituting the above expansions (3.1)-(3.3) in the equations (2.6)-(2.8) and equating the like powers of δ, we obtain equations to the zero th order as

$$\frac{d^2u_0}{dy^2} + S\frac{du_0}{dy} = \pi \quad (3.4)$$

$$\frac{d^2\theta_0}{dy^2} + SP\frac{d\theta_0}{dy} - \alpha\,P\theta_0 = 0 \quad (3.5)$$

$$\frac{d^2C_0}{dy^2} + SSc\frac{dC_0}{dy} - \gamma C_0 = 0 \quad (3.6)$$

The first order equations are

$$\frac{d^2u_1}{dy^2} + S\frac{du_1}{dy} = -G(\theta_0+NC_0) + (D^{-1}+M^2)\,u_1 - \mathrm{A}u_0^2 \quad (3.7)$$

$$\frac{d^2\theta_1}{dy^2} + SP\frac{d\theta_1}{dy} - \alpha P\theta_1 = 0 \quad (3.8)$$

$$\frac{d^2C_1}{dy^2} + SSc\frac{dC_1}{dy} - \gamma C_1 = 0 \quad (3.9)$$

The second order equations are

$$\frac{d^2u_2}{dy^2} + S\frac{du_2}{dy} = -G(\theta_1+NC_1) + (D^{-1}+M^2)\,u_2 - \mathrm{A}u_1^2 \quad (3.10)$$

$$\frac{d^2\theta_2}{dy^2} + SP\frac{d\theta_2}{dy} - \alpha P\theta_2 = 0 \quad (3.11)$$

$$\frac{d^2C_2}{dy^2} + SSc\frac{dC_2}{dy} - \gamma C_2 = 0 \quad (3.12)$$

The corresponding boundary conditions are

$$u_0(\pm1) = 0,\; \theta_0(-1) = 0,\; C_0(-1) = 0$$
$$\theta_0(+1) = 1,\; C_0(+1) = 1 \quad (3.13)$$

$$u_1(\pm1) = 0,\; \theta_1(\pm1) = 0,\; C_1(\pm1) = 0 \quad (3.14)$$

$$u_2(\pm1) = 0,\; \theta_2(\pm1) = 0,\; C_2(\pm1) = 0 \quad (3.15)$$

Solving the equations (3.4)-(3.12) subject to the boundary conditions (3.1)-(3.3) we obtain

$$u_0 = a_2\left(\exp(-sy) - Cos\,h(sy)\right)$$

$$u_1 = a_{19} + a_{20}\exp(-sy) + \varphi_1(y)$$

$$\varphi_1(y) = a_{11}y - a_{12}y^2 - a_{13}\,y\exp(-sy) - a_{14}\exp(-M_1y) - (a_{15}+a_{16})\exp(-M_2y) - a_{17}\exp(-M_3y) - a_{18}\exp(-M_4y)$$

$$u_2 = a_{25} + a_{26}\exp(-sy) + \varphi_2(y)$$

$$\varphi_2(y) = a_{58}y + a_{59} + a_{60}y^2 + a_{49}y^3 + \frac{1}{2s^2}\exp(-2sy) + \frac{1}{6s^2}\exp(2sy) + a_{53}\exp(-M_1y) + a_{54}\exp(M_2y) + a_{55}\exp(M_3y) + a_{56}\exp(M_4y) + (a_{61}+a_{43}y^2+a_{45})\exp(-sy) + a_{57}\exp(sy)$$

$$\theta_0 = a_3\exp(M_1y) + a_4\exp(M_2y)$$

$$\theta_1 = 0$$

$$\theta_2 = 0$$

$$C_0 = a_5\exp(-M_3y) + a_6\exp(M_4y) + a_7\exp(-M_1y) + a_8\exp(M_2y)$$

$$C_1 = 0$$

$$C_2 = 0$$

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IV. Stress, Nusselt Number and Sherwood Number

The shear stress on the boundaries $y = \pm 1$ are given by $\tau^{\bullet} = \left(\mu \dfrac{du}{dy} \right)_{y=\pm L}$

which in the non-dimensional form reduces to

$$\tau = \frac{\tau^{\bullet}}{(\nu^2 / L^2)} = \left(\frac{du}{dy} \right)_{y=\pm 1}$$

$$= \left(\frac{du_0}{dy} + \delta \frac{du_1}{dy} + \delta^2 \frac{du}{dy} \right)_{y=\pm 1}$$

and the corresponding expressions are

$$\tau_{y=+1} = b_3 + \delta b_5 + \delta^2 b_7 + ...$$

$$\tau_{y=-1} = b_4 + \delta b_6 + \delta^2 b_8 + ...$$

The rate of heat transfer (Nusselt Number) on the boundaries $y = \pm 1$ are given by

$$Nu_{y=\pm 1} = \left(\frac{d\theta_0}{dy} + \delta \frac{d\theta_1}{dy} + \delta^2 \frac{d\theta_2}{dy} \right)_{y=\pm 1}$$

and the corresponding expressions are

$$Nu_{y+11} = b_7$$

$$Nu_{y=-1} = b_8$$

The rate of mass transfer (Sherwood Number) on the boundaries $y = \pm 1$ are given by

$$Sh_{y=\pm 1} = \left(\frac{dC_0}{dy} + \delta \frac{dC_1}{dy} + \delta^2 \frac{dC_2}{dy} \right)_{y=\pm 1}$$

and the corresponding expressions are

$$Sh_{y+11} = b_9$$

$$Sh_{y=-1} = b_{10}$$

V. Discussion of the Numerical Results

The aim of this analysis is to investigate the convective heat and mass transfer through a porous medium in a chemically reacting fluid in a vertical channel in the presence of heat sources. We consider three different cases k > 0, k = 0 and k < 0, where k is the chemical reaction parameter. k > 0 represents destructive chemical reaction, k = 0 represents no chemical reaction and k < 0 is for generative chemical reaction.

The velocity u is represented in figs.1-7 for different values of the governing parameters G, D^{-1}, Sc, S, M, N, N_1, α and k. u > 0 is the actual flow and u < 0 is the reversal flow. It is found that the velocity profiles rises from its value zero on the boundary y = -1 to attain the prescribed value 1 on y = 1.The axial velocity enhances with increase in G and reduces with increase in the strength of the heat generating source(fig.1).Fig.2 represents the variation of u with reference to D^{-1} and M. It is found that lesser the permeability of porous medium or higher the Lorentz force smaller u in the flow field. From fig.3 we notice that when the molecular buoyancy force dominates over the thermal buoyancy force the axial velocity u experiences an enhancement in the flow region when the buoyancy forces act in the same direction and for the forces acting in different directions we notice a depreciation in u in the entire flow region. Also an increase in the radiation parameter N_1 leads to an enhancement in u in the flow region except in the vicinity of y=1. The variation of u with Schmidt number Sc reveals that smaller the molecular diffusivity lesser the axial velocity in the flow field (fig.5).Figs.6&7 represents the behavior of u with reference to the suction parameter S and the chemical reaction parameter k.We notice that u enhances with increase in S.It is found that the velocity decreases during the generative reaction and enhances in the destructive reaction.

The non-dimensional temperature (θ) is shown in figs.8-12.The temperature is found to be positive for all variations. The non-dimensional temperature depreciates with α(fig.8).An increase in the molecular diffusivity leads to a depreciation in θ in the entire flow field (fig.9).The behavior of θ with the suction parameter S indicates that the temperature enhances with increase in S(fig.10).The variation of θ with the chemical reaction parameter k (fig.11) shows that θ decreases in the generative reaction and enhances in the destructive reaction. The behavior of θ with the radiation parameter N_1 is depicted in fig.12.The temperature experiences a remarkable depreciation when the radiation parameter enhances and for higher values of N_1there is a marginal decrease in θ in the entire flow region.

The concentration distribution (C) is exhibited in figs.13-15.It is found that the concentration is positive in the entire flow region for all variations.Fig.13 exhibits the variation of C with Sc. We find that lesser the molecular diffusivity smaller the concentration in the flow field, The effect of suction parameter S is shown in fig.14.We notice that higher the suction at the boundaries larger the concentration in the flow region. From fig.15 we observe that there is a fall in the concentration for destructive chemical reaction and an enhancement in C for generative chemical reaction.

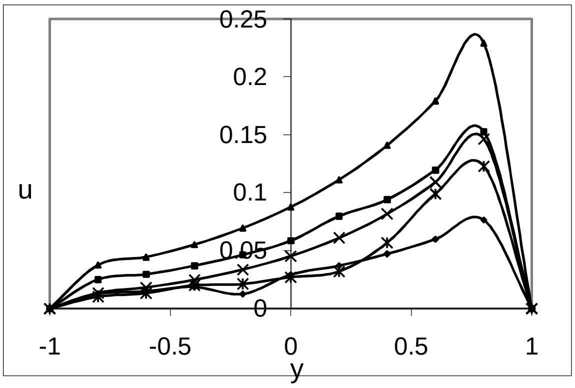

Fig.1 Variation u with G & α

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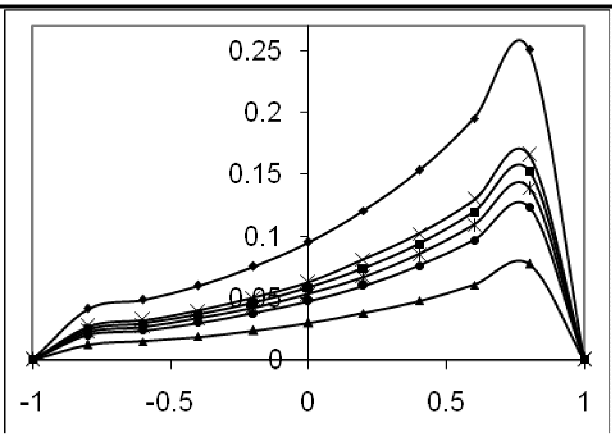

Fig.2 Variation of u with D^{-1}& M

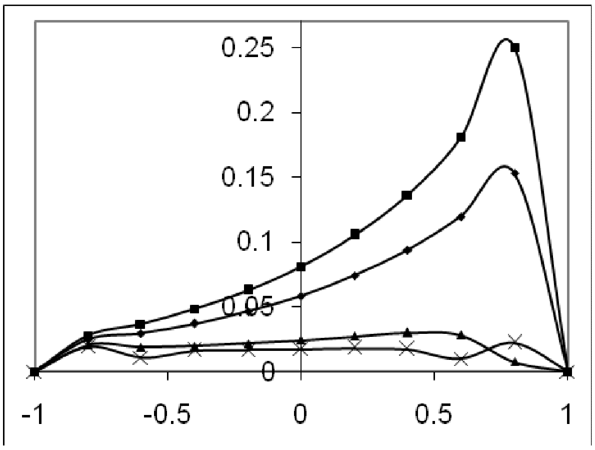

Fig.3 Variation u with N

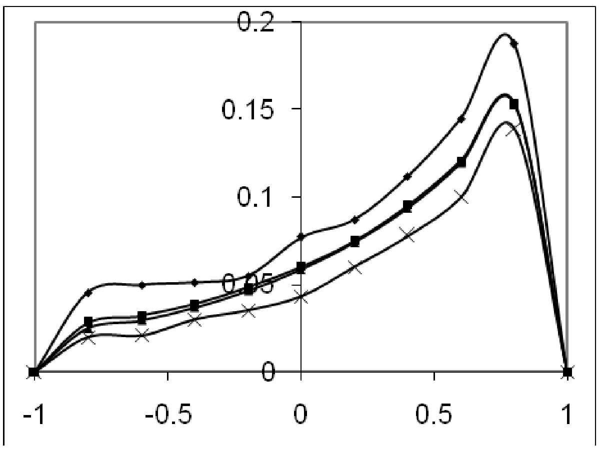

Fig.4 Variation u with N_1

Fig.5 Variation u with Sc

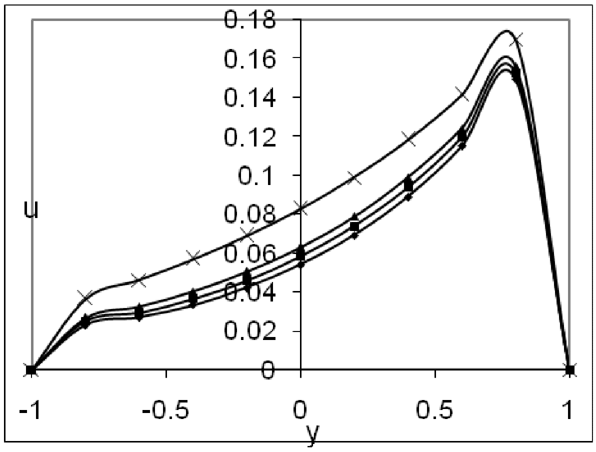

Fig.6 Variation u with S

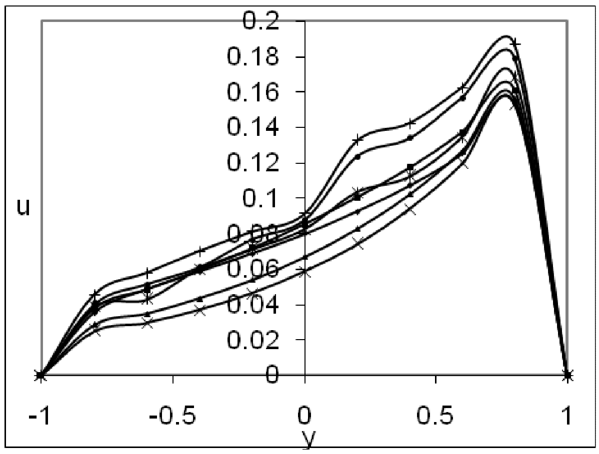

Fig.7 Variation u with k

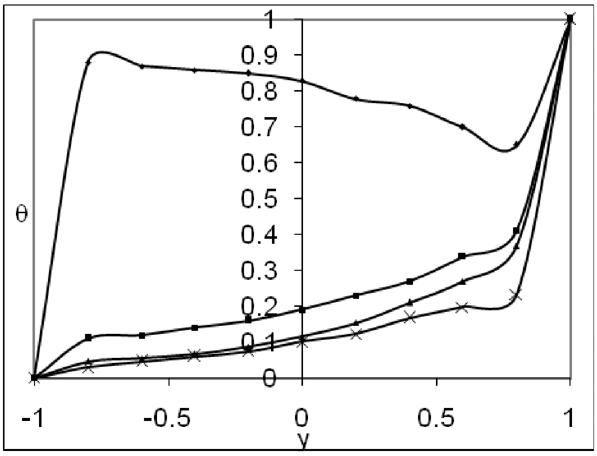

Fig.8 Variation θ with α

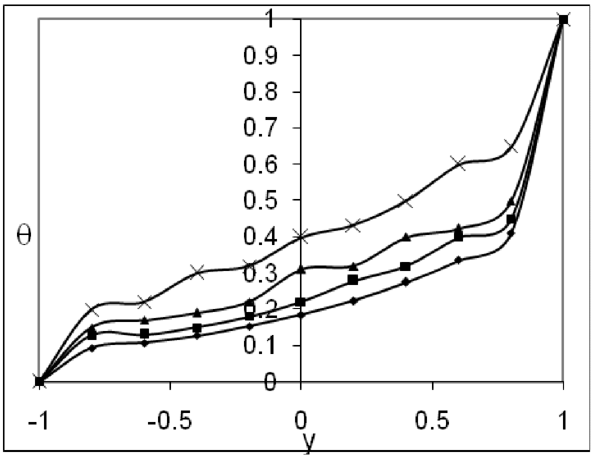

Fig.9 Variation θ with Sc

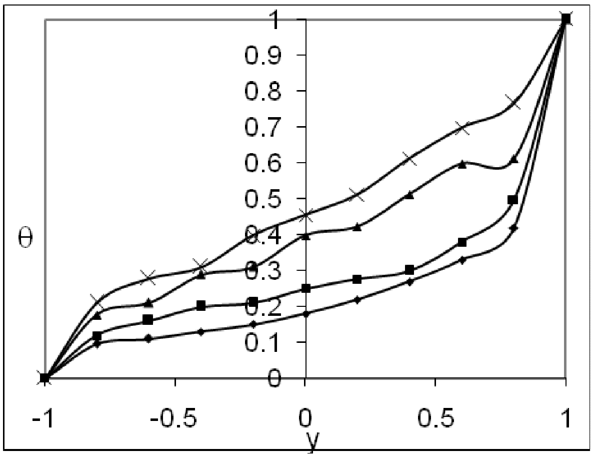

Fig.10 Variation θ with S

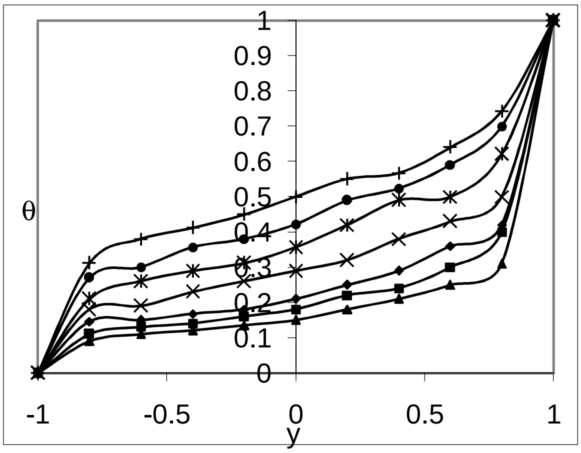

Fig.11 Variation θ with k

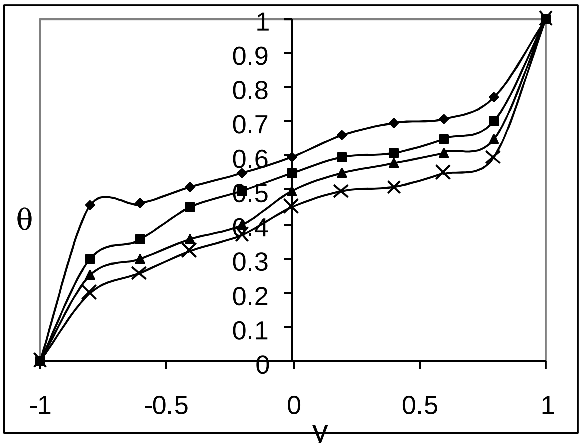

Fig.12 Variation θ with N_1

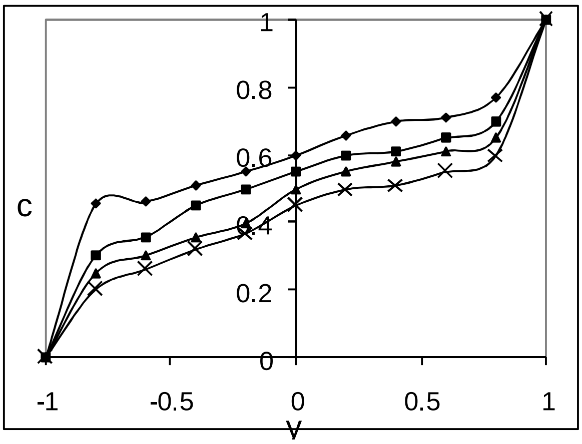

Fig.13 Variation C with Sc

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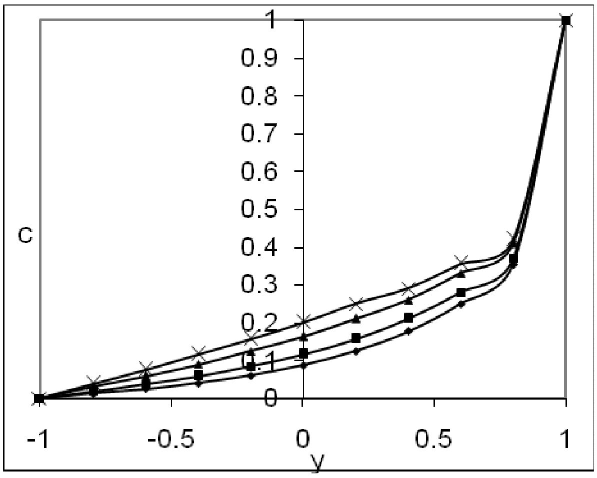

Fig.14 Variation C with S

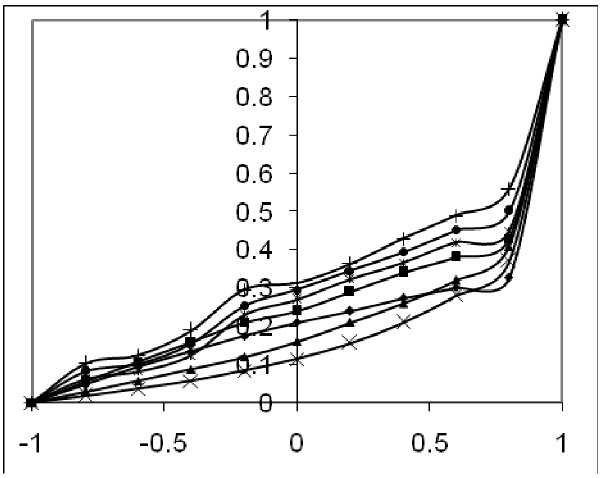

Fig.15 Variation C with k

The average Nusselt number (Nu) which represents the rate of heat transfer at y = ±1 is shown in tables.1,2 for different values of G,D^{-1} , N and α. The variation of Nu with D^{-1}shows that lesser the permeability of the porous medium larger the magnitude of Nu at y+1 and at y = -1 smaller │Nu│ and for further lowering of the permeability larger │Nu│at both the walls. The variation of Nu with α shows that the rate of heat transfer depreciates with α < 4 and enhance with higher α ≥ 6 at both the walls. Lesser the molecular diffusivity larger │Nu│at y = +1, smaller │Nu│ at y = -1 for G > 0and for G < 0smaller │Nu│ at y = +1 and larger │Nu│ at y = -1.

The Sherwood Number (Sh) which measures the rate of mass transfer at y = ±1 is shown in tables.3,4 for different variations. The variation of Sh with D^{-1}shows that lesser the permeability of the porous medium smaller the rate of mass transfer at y = 1 and larger at y = -1.The variation of Sh with Sc shows that lesser the molecular diffusivity larger │Sh│ at y = ±1 in the heating case while in the cooling case it enhances at y = 1 and reduces at y = -1.The rate of mass transfer reduces at y = +1 and enhances at y = -1 when the buoyancy forces act in the same direction and for the forces acting in opposite directions │Sh│enhances at y = 1 and depreciates at y = -1.

Table-1
Nusselt Number Nu_1 at y = 1

G	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-3.9534	-4.341	-4.9488	0.98614	3.1053	-3.9534	-3.8856	-4.0793	-4.1058
$3x10^3$	-3.9625	-4.344	-4.9508	0.33058	2.9179	-3.9625	-3.8935	-4.0906	-4.1176
10^3	-3.9908	-4.3534	-4.9567	3.9822	3.5135	-3.9908	-3.9184	-4.1266	-4.1545
$3x10^3$	-3.9812	-4.3502	-4.9547	8.8482	3.7362	-3.9812	-3.91002	-4.114	-4.1419
D^{-1}	10^2	$2x10^2$	$3x10^2$	10^2	10^2	10^2	10^2	10^2	10^2
α	2	2	2	4	6	2	2	2	2
N	1	1	1	1	1	1	2	-0.5	-0.8

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Table-2

Nusselt Number Nu_2 at y = -1

G	I	II	III	IV	V	VI	VII	VIII	IX
10^3	7.8348	7.2854	7.6377	0.2104	-2.9962	7.8348	7.7106	8.0655	8.1138
$3x10^3$	7.8519	7.2883	7.6377	1.54509	-2.5	7.8519	7.7256	8.0866	8.1359
10^3	7.9051	7.2971	7.6375	-5.88946	-4.0767	7.9054	7.7724	8.1528	8.205
$3x10^3$	7.8870	7.2941	7.6376	-5.7963-	4.6664	7.887	7.7565	8.1303	8.1815
D^{-1}	10^2	$2x10^2$	$3x10^2$	10^2	10^2	10^2	10^2	10^2	10^2
α	2	2	2	4	6	2	2	2	2
N	1	1	1	1	1	1	2	-0.5	-0.8

Table-3

Sherwood number (Sh) at y = 1

G	I	II	III	IV	V	VI	VII	VIII
10^3	-0.2943	-0.15737	-0.15307	-0.31362	-0.3176	-0.18498	-0.22211	-0.36752
$3x10^3$	-0.29536	-0.15734	-0.15302	-0.31497	-0.3190	-0.18518	-0.2226	-0.36916
10^3	-0.29866	-0.15726	-0.15285	-0.31915	-0.3234	-0.18579	-0.22412	-0.37426
$3x10^3$	-0.29754	-0.15729	-0.15290	-0.31773	-3.3219	-0.18558	-0.22361	-0.37253
D^{-1}	10^2	$2x10^2$	$3x10^2$	10^2	10^2	10^2	10^2	10^2
N	1	1	1	-0.5	-0.8	1	1	1
Sc	1.3	1.3	1.3	1.3	1.3	0.24	0.6	2.01

Table-4

Sherwood number (Sh) at y = -1

G	I	II	III	IV	V	VI	VII	VIII
10^3	-1.28231	4.8048	47.7192	-1.2935	-1.2956	-1.2688	-1.2789	-1.2833
$3x10^3$	-1.28277	4.5436	42.324	-1.2939	-1.2959	-1.2763	-1.2811	-1.2832
10^3	-1.2841	4.8781	31.4922	-1.2949	-1.2969	-1.2953	-1.2872	-1.28313
$3x10^3$	-1.28366	4.0825	34.4518	-1.2946	-1.2966	-1.2895	-1.2852	-1.28317
D^{-1}	10^2	$2x10^2$	$3x10^2$	10^2	10^2	10^2	10^2	10^2
N	1	1	1	-0.5	-0.8	1	1	1
Sc	1.3	1.3	1.3	1.3	1.3	0.24	0.6	2.01

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